



**Federal Aviation
Administration**

DOT/FAA/AM-07/25
Office of Aerospace Medicine
Washington, DC 20591

An International Survey of Maintenance Human Factors Programs

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September 2007

Final Report

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Technical Report Documentation Page

1. Report No. DOT/FAA/AM-07/25	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle An International Survey of Maintenance Human Factors Programs		5. Report Date September 2007	
		6. Performing Organization Code	
7. Author(s) Hackworth C, ¹ Holcomb K, ¹ Dennis M, ¹ Goldman S, ² Bates C, ³ Schroeder D, ¹ and Johnson W ⁴		8. Performing Organization Report No.	
9. Performing Organization Name and Address ¹ FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125 ² Oklahoma State Department of Health Oklahoma City, OK 73117 ³ University of Oklahoma Psychology Department Norman, OK 73019 ⁴ Federal Aviation Administration Atlanta, GA 30319		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, D.C. 20591		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes Work was accomplished under approved task AM-B-06-HRR-521.			
16. Abstract There are many international approaches to the regulation of human factors programs for aviation maintenance organizations. Transport Canada and the European Aviation Safety Agency have established specific regulations regarding maintenance human factors. The Federal Aviation Administration has not yet established regulations but, instead, has created guidance documents and developed voluntary reporting programs for maintenance organizations. The purpose of this study was to assess the status of human factors programs in airline maintenance organizations and independent maintenance and repair organizations. Questions focused on training, error management, fatigue management, and other human factors issues. An online link was sent via E-mail to 630 addresses. Of these, 414 respondents returned a valid questionnaire (i.e., defined as responding to at least one content item), which resulted in a response rate of 66%. A highly-experienced group (i.e., over 65% had 20 years in aviation maintenance) from more than 50 countries responded to the questionnaire. Results highlight the maintenance human factors strategies, methods, and programs that companies use to reduce human error.			
17. Key Word Aviation Maintenance Human Factors, Human Error, Aviation Maintenance Practices		18. Distribution Statement Document is available to the public through the Defense Technical Information Center, Ft. Belvoir, VA 22060; and the National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 28	22. Price

ACKNOWLEDGMENTS

The research team is grateful to all respondents and colleagues who participated in the design and completion of this study.

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AN INTERNATIONAL SURVEY OF MAINTENANCE HUMAN FACTORS PROGRAMS

INTRODUCTION

United States (U.S.) airlines invest more than \$10 billion annually to ensure the airworthiness of their fleets (Boeing, 2005). Boeing and the U.S. Air Transport Association (as cited in Rankin, Hibit, Allen, & Sargent, 2000) found that maintenance-related errors were associated with up to 15% of commercial aircraft hull loss accidents from 1982 through 1991. In the 2003 International Air Transport Association (IATA) safety report following a review of 92 accidents, they found that a maintenance factor initiated the accident chain in 26% of the accidents. Maintenance errors are responsible for an estimated 20 to 30% of engine in-flight shutdowns, costing approximately \$500,000 per shutdown (W. Rankin, personal communication, August 11, 2005). This would argue that the airlines and Maintenance and Repair Organizations (MROs) must continue to invest in human factors (HF) programs within maintenance organizations and also on the flight deck.

While not the primary cause of aviation accidents in Australia, maintenance-related errors contribute to 4.5% of the overall aircraft accidents. In 1998, an Australian project surveyed licensed aircraft maintenance engineers. The study focused on the events and conditions that pose a risk to the safety of the aircraft or maintenance workers. The most common occurrence reported in the survey involved situations where aircraft systems were operated in an unsafe manner during maintenance. Incomplete component installation was the second leading occurrence. More than 95% of these occurrences involved human error. The most common errors involved memory lapses and procedural shortcuts. Time pressures, equipment deficiencies, inadequate training, coordination difficulties, and fatigue are examples of factors believed to precipitate these events. The Australian Transportation Safety Board (ATSB) recommended several areas that needed to be addressed to mitigate the identified concerns. They included: programs addressing fatigue, improved recurrent training, crew resource management, and eliminating a blame culture (ATSB, 2001).

Human error is documented as a causal factor within maintenance-related accidents (Boquet, Detwiler, Holcomb, Hackworth, Shappell, & Weigmann, unpublished manuscript; Johnson & Watson, 2001). Wells (2001) reported that HF issues are believed to be a factor in 50% of maintenance-related accidents. Maintenance errors can generally be divided into two major classes: failing to

detect a problem or the introduction of an error during maintenance (Marx & Graeber, 1994). Patankar, Lattanzio, & Kanki (2004) examined maintenance Aviation Safety Reporting System (ASRS) procedural error reports. Within their analysis, several error themes emerged under the category of user error. Examples of these user errors included mechanics not reading or following the maintenance manual, mechanics overlooking required inspection items, and mechanics making logbook errors.

Companies are faced with implementing corrective actions in response to these errors and must realize how to prevent such errors. This requires organizations to move from blaming an individual worker to implementing a systemic approach to handle maintenance errors. Johnson (2001) suggested that HF programs can improve safety and reduce vulnerability to error—while maintaining efficiency. Therefore, remedial actions must improve performance, ensure that safety policies and practices are consistent, and, in doing so, reduce costs. Recently, the Federal Aviation Administration (FAA) released the *Operator's Manual for Human Factors in Aviation Maintenance* (FAA, 2006a). The manual includes chapters highlighting the impact of event investigation systems, proper use of technical documentation, HF training, shift and task turnover procedures, and fatigue.

Effective HF programs, however, require commitment. Komarniski (2006) recently highlighted the requirements of a successful maintenance human factors (MHF) program. Buy-in from management, as well as the maintenance staff, is integral. With full support, attention to HF becomes a part of the culture, day-to-day operations, and an important, protected line in the budget.

There are a variety of international approaches to the regulation of HF programs for maintenance organizations. Transport Canada (TC) and the European Aviation Safety Agency (EASA) have established specific, yet differing, regulations regarding MHF. These pertain to such items as initial and continuation training and formal error-reporting systems. The FAA has not yet established regulations but, instead, has created guidance documents and developed voluntary reporting programs for maintenance organizations. For now, the FAA has chosen to adopt a voluntary rather than a regulatory approach to MHF.

Objective one of the FAA's 2006-2010 Strategic Plan (FAA, 2006b) Increased Safety Goal intends "to reduce the commercial airline fatal accident rate." Another Flight Plan goal targets the provision of international technical

leadership. In support of these objectives, the FAA conducted this international survey of maintenance-related companies to examine employee perceptions of how companies are implementing MHF initiatives.

This project assessed the effect of voluntary versus regulatory approaches to MHF programs. How are organizations applying HF principles in their day-to-day operations? What is the effect of a MHF program on the organization and on aviation maintenance personnel? Additionally, is there a significant difference in the implementation of MHF programs across the international spectrum?

This paper describes a variety of safety practices and opinions prevalent among HF managers, quality control managers/executives, HF trainers, and labor organization representatives that work in the international airline maintenance industry. Because we were unable to systematically sample respondents, our conclusions are limited to a descriptive nature and do not necessarily reflect the opinions or practices of the entire aviation maintenance population. However, based on our sample, as described later in the paper, we are reasonably certain that we have respondents who represent the “best case” representation of international MHF programs.

METHOD

Potential respondents were identified in coordination with the Joint Aviation Authority Human Factors Working Group (primarily comprised of EASA member states), several airlines, and FAA representatives. Publications, including newsletters and notices, were sent to encourage international participation. Invited respondents worked in maintenance organizations as engineers, quality assurance specialists, maintenance directors, and mechanics. Respondents volunteered to participate in advance of receiving the questionnaire.

Questionnaire Content

The questionnaire contained 66 items with 12 potential follow-up items. Follow-up items were presented based upon pre-specified responses to specific items. Items were organized into eight categories: (1) demographics, (2) error management, (3) HF training, (4) fatigue management, (5) proactive HF support, (6) motivation for an HF program, (7) HF metrics, and (8) organizational policies. The questionnaire asked respondents for additional information about their company’s maintenance program and any general comments about the survey. See Appendix A for the complete questionnaire.

Individual/organizational demographics. Respondents were asked to provide basic organizational and general individual demographic information. These items in-

cluded specifying the type of maintenance operation in which the respondent was currently employed, country of employment, primary regulatory authority, job title, number of employees in their organization, and years of experience in aviation maintenance.

Error management. Respondents were asked to comment on their organization’s approach to human error investigations, including how they used the data. There was one open-ended comment item for additional remarks about error management.

Human factors training. Respondents were asked about their organization’s approach to HF training. The items focused on how much and what type of HF training was provided for employees of the organization, the type of employees who received the training, and the credentials of the maintainers (e.g., licensed or unlicensed). One additional item allowed respondents to provide remarks regarding HF training.

Fatigue management. Respondents were asked if their organization currently had a fatigue management system, provided training on fatigue management, and if the organization recognized fatigue as a safety issue.

Proactive human factors support. This section assessed whether the respondent’s organization valued their MHF program. Included were items inquiring if management supported the MHF program in words and action.

Motivation for human factors program. Respondents were asked to rate the importance of various factors to their organization when they implemented a MHF program (regulatory compliance, safety, or cost).

Human factors metrics. This section focused on the metrics utilized by the respondent’s organization to assess their HF program. Additionally, respondents were asked whether the organization utilized cost-benefit and return-on-investment calculations to assess their HF program.

Organization’s policies. Respondents answered questions on the formal or informal policies in place regarding HF issues. For example, respondents were asked about their company’s shift handover policy and safety policy.

Respondent comments. Two items directly asked respondents for general feedback regarding their organization’s maintenance program and for any additional comments about the survey.

Sample Distribution

An E-mail invitation was sent to 647 potential respondents. The E-mail included an explanation of the purpose of the questionnaire, as well as a link to the survey, including username/password information. All questionnaires were conducted online using the SurveySage © system. Three reminder E-mails were sent over a one-month period following the initial invitation. The reminder prompted the potential respondent of the existence and

purpose of the questionnaire. The questionnaire was open to respondents for one month from the initial invitation, after which the questionnaire was taken offline. Of the 630 valid E-mail invitations, 414 returned a valid questionnaire (i.e., defined as responding to at least one content item), which resulted in a response rate of 65.7%.

Sample Demographics

Respondents represented several occupations within the maintenance workforce, including: management, quality control, training, and labor (see Table 1). The respondents were employed in more than 50 countries. Not surprisingly, given the origin of the survey, many respondents (39.8%) worked within the United States. However, respondents from many other countries participated, including: Canada (8.7%), United Kingdom (7.2%), Australia (3.2%), Norway (3.0%), and Singapore (3.0%). A listing of all participating countries is included in Appendix B.

A majority of the respondents had a long history within aviation maintenance, with 64.9% indicating more than 20 years of experience. Respondents worked in maintenance departments where the median number of employees at their company or engineering maintenance department was 300 with a range from a minimum of 1 to a maximum of 50,000.

The survey sample covered the entire aircraft maintenance industry, with more than one-third from an airline maintenance department, 27.3% from repair stations, 8.9% general aviation/business operations, and 5.6% from a training facility or maintenance school (Fig. 1).

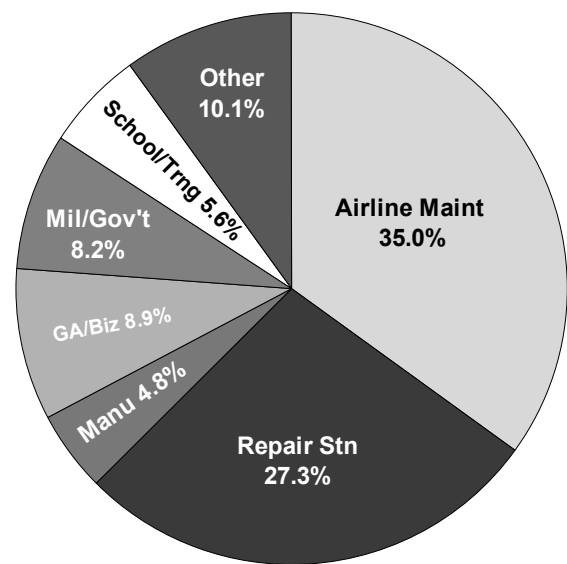


Figure 1. Employment Facility of Respondents.

For those who reported that they worked for an airline maintenance department or repair station, nearly two-thirds were from a major carrier, slightly over 20% were at a regional carrier, and the remaining worked in air taxi and corporate operations.

When asked for the primary regulatory authority that their company's maintenance operations were designed to comply with, the majority of respondents indicated the FAA (45.0%). However, as an indication of the diversity of responses, other authorities were identified as well. See Table 2 for a summary.

Table 1. Job Title of Respondents.

Job Role Title	% of Respondents
Supervisor/Manager/Coordinator	37.1
Quality Assurance/Quality Control/Airworthiness	28.4
Training	11.9
Engineering	6.2
Technician/Mechanic	4.4
Consultant/Professor	3.9
Inspector/Investigator	3.4
Labor Representative	3.1
Safety Analyst	1.8

Table 2. Primary Regulatory Authority to Which Maintenance Operations Were Designed to Comply.

Regulatory Authority Model	N	%
Federal Aviation Administration (FAA)	182	45.0
European Aviation Safety Agency (EASA)	95	23.5
Local National Aviation Authority (O-NAA)	72	17.8
Transport Canada (TC)	36	8.9
Civil Aviation Safety Authority (CASA)(Australia)	19	4.7

Data Analysis

Frequencies and proportions were calculated for each response option across items. Percent positive was calculated by summing the top two response categories on the agreement (i.e., agree and strongly agree) and the importance (i.e., considerable and great importance) scales.

For several items, results are split by regulatory authority model (i.e., CASA, EASA, FAA, TC, and O-NAA). Keep in mind that this was the regulatory body that their company designed their maintenance programs to be in compliance with and, therefore, possibly not their country's regulatory agency. We make this point because some companies across the world may follow FAA or EASA regulations even though they are not regulated by either of those agencies.

RESULTS

Motivation for Human Factors Program

Though there are many advantages to instituting an HF program within a maintenance operation, when asked to rate independently the importance of several factors when their organization implemented an HF program, 85.7% reported that flight safety was of considerable to great importance. Worker safety was also a high priority, at 80.9%. Further, over three-fourths (79.9%) indicated that regulatory compliance was also a strong motivator. Overall, cost was least important, at 59.7%.

When we examined responses by regulatory model, we found that *flight safety* was of the highest importance for CASA, FAA, and O-NAA. For EASA and TC, *regulatory compliance* was of a high degree of importance. See Figure 2 for all responses.

Regulator Support

Slightly over 40% reported receiving support from their regulator for the implementation of their HF program, and 33.9% worked closely with their regulator to monitor their HF program. When *support* and *working closely* were broken out by regulatory model, respondents complying with TC reported the highest level of support (57.1%), while those under O-NAA indicated the closest working relationship (44.4%). See Table 3 for all responses.

Proactive Human Factors Support

Respondents indicated encouragement from their manager/director of maintenance, with 64.8% reporting that senior management demonstrated support in words and action for MHF. Fifty-nine percent indicated (agree or strongly agree) that they had a formal means for supervisors and workers to provide suggestions on HF issues. When split by regulatory model, EASA respondents, by far, expressed the highest agreement, at 71.4%.

This is in contrast to the second-highest group, O-NAA respondents, at 60.9% (Table 4).

Keeping the lines of communication open between HF personnel and senior management is essential for a successful HF program. Thirty-nine percent reported that their company employed a formal method for their HF specialist(s) to provide regular briefings to senior maintenance management.

Close to 80% recognized the value of proactive HF programs. However, only 11.5% indicated HF was an explicit line item in their company's budget.

Of the 127 respondents who indicated the U.S. was their country of employment and their regulatory model was the FAA, 48.8% indicated that they participated in the FAA's Aviation Safety Action Program (ASAP),

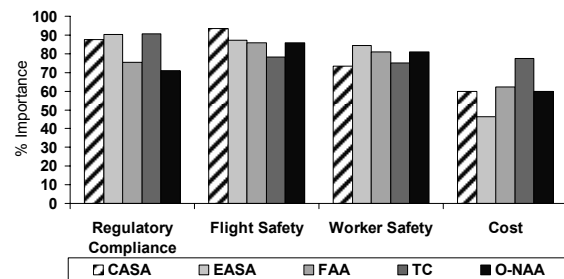


Figure 2. Motivating Factors for Human Factors Program.

Table 3. Level of Support by Regulatory Model.

Regulatory Model	Support % Agreement	Work Closely % Agreement
TC	57.1	35.7
CASA	46.2	28.6
O-NAA	39.3	44.4
EASA	39.1	28.6
FAA	38.3	31.9

Table 4. Formal Means for Supervisors and Workers to Provide Suggestions.

Regulatory Model	% Agreement
EASA	71.4
O-NAA	60.9
FAA	55.5
TC	53.3
CASA	46.7

and 9.4% reported that their company was initiating actions to participate. This high ASAP participation by our respondents reinforces the fact that our data include many of the “best case” examples of operators in the U.S. However, ASAP participation across all repair stations and U.S. carriers is much smaller.

Nearly 36% of respondents indicated that they were active participants in industry or HF working groups. When examined by regulatory model, figures ranged from 31.3% to 44.8%, with TC leading the way.

Organizational Policies

The majority of respondents (72.3%), reported that they had a formal quality assurance (QA) process such as ISO9000. When asked if their QA program addressed HF, 46.3% said “yes” and 10.2% said “don’t know.” Most (88.6%) reported that their company had a formal safety policy, and an additional 7.8% reported an informal safety policy. These figures were fairly consistent regardless of regulatory model. See Tables 5 and 6 for all responses.

Over 60% reported a formal shift handover policy, and an additional 22% reported an informal policy. See

Table 5. Quality Assurance Processes by Regulatory Model.

	% QA Process	% QA Process Addresses HF
Overall	72.3	46.3
O-NAA	75.0	55.6
FAA	74.0	37.5
EASA	69.9	55.6
CASA	66.7	40.0
TC	66.7	50.0

Table 6. Formal and Informal Safety Policy by Regulatory Model.

	Safety Policy	
	% Formal	% Informal
Overall	88.6	7.8
CASA	100.0	0.0
EASA	93.1	4.2
FAA	88.7	7.3
TC	90.0	10.0
O-NAA	80.0	13.8

Figure 3 for a breakout of shift handover policy across regulatory model. Results were fairly similar; however, respondents that reported their HF practices were in line with EASA were most likely to have a shift handover policy (92.9%).

Interestingly, less than half (42.7%) reported their company had a formal policy to apply HF principles in writing or amending technical documentation. However, an additional 28% indicated an informal policy.

Human Factors Training

The issue of HF is introduced as part of training for new maintenance personnel by 66.6% of the represented companies. Further, 79.6% (agree and strongly agree) recognized the return on investment of initial HF training, and 76.1% recognized the return on investment of recurrent HF training.

Given differences in HF requirements across regulatory agencies, we suspected that there could be differences in the maturity of training programs. Indeed, this is what we found in that TC (77.4%) and EASA (71.6%) respondents reported having an existing course that met requirements. Respondents regulated by the FAA had the lowest percentage (43.4%) regarding an existing HF course. See Figure 4 for all responses.

However, as is clear from the figure, it was not as if others were absent of training. In fact, their companies were in the process of developing a course, sending

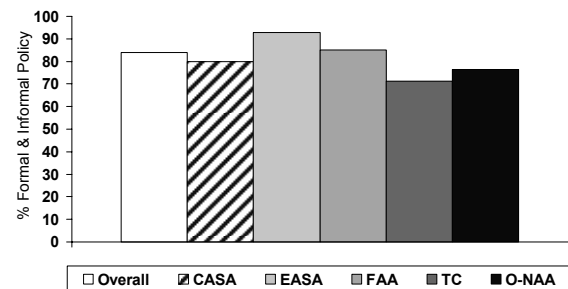


Figure 3. Shift Handover Policy by Regulatory Authority Model.

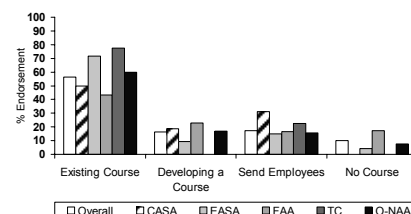


Figure 4. Current Position Regarding HF Training.

their employees to an existing course, or they had hired a consultant for training. One area in need of improvement was found for those that designed their program in compliance with the FAA. Over 17% of these respondents reported no course.

For respondents that reported having an HF course or were in the process of developing a course, the topic areas of the course were in line with best practices. For example, many reported that communication, human error, and factors related to fatigue were covered (Table 7).

Table 7. Topic Areas of Human Factors Course.

Topic Area	%
Introduction to HF	96.4
Factors that contribute to human error	96.0
Communications	92.4
Effect of shift work and fatigue on performance	89.8
Event Investigation	74.7
Shift turnover	78.2
Other topics	32.9

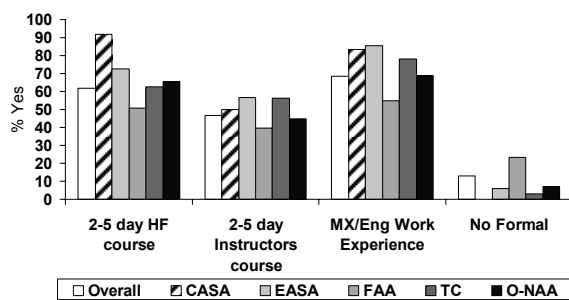


Figure 5. Training of HF Trainers.

Table 8. Percentage Storing Error Data in a Database by Regulatory Authority.

Regulator	% in Database
Overall	55.0
EASA	65.1
O-NAA	57.4
TC	56.3
CASA	53.8
FAA	49.1

When asked about the breadth of their company's HF trainers, the majority of respondents (68.5%) reported that their trainers had maintenance/engineering work experience. Many trainers were said to have attended a 2-5 day HF course (61.7%) and/or a 2-5 day instructors' skills course (46.8%). Only a few (12.9%) reported that their HF trainers had no formal HF training. When we examined the results by regulatory model, CASA, EASA, and TC clearly had instructors with a well-trained and experienced background (Fig. 5). By comparison, for those companies that modeled their program after the FAA, a higher percentage (23.4%) of their trainers were said to have no formal training.

Error Management

One of the key factors for a successful MHF program is the availability of a program to track maintenance error events. Over half (55%) of the respondents reported that their error data were stored in a database. Differences were observed across regulatory model. Companies modeling EASA requirements reported the highest storage of error data (65.1%), while those modeling the FAA were the lowest at 49.1%. See Table 8 for all responses.

Overall, organizations reported employing either a formal (64.8%) or informal (19.1%) program for their human error investigations. Of these organizations, 32.2% reported using the Maintenance Error Decision Aid (MEDA), 10.5% the Human Factors Analysis and Classification System (HFACS), 36.6% some modification of MEDA, and 35.1% indicated they used another program not listed.

Moving beyond storage of data and investigating single incidents, we wanted to know if companies had systemic programs in place to review and use their error data to prevent future occurrences. Tracking trends and the progress of interventions support the sustainment of an HF program. We found less positive results within this area. For example, less than half (46.5%) of our respondents indicated that their company reviewed their database in a proactive manner (Table 9).

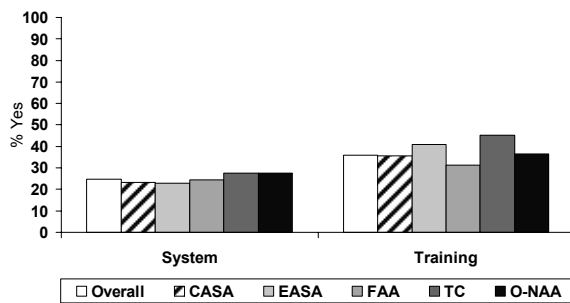
Moreover, most respondents (70.5%) indicated that their company generated recommendations from individual incidents but did not evaluate the effectiveness of interventions.

Fatigue Management

Over half (51.3%) of the respondents indicated that managing fatigue was an important element of their safety management system. The impact of fatigue on safety was recognized by 82.1%. However, only 24.9% indicated that their organization had a fatigue management system. This figure was fairly consistent across regulatory models. The inconsistency between belief and action was further

Table 9. Use of Human Error Data.

Recommendations are made from individual incidents investigated.	70.5%
We review our error database periodically to identify concerns and plan interventions.	46.5%
Senior management uses the information as part of a formal quality management process.	43.1%
Within the past year, processes and procedures were changed as a result of the analysis of the error database.	33.7%
Interventions are evaluated to assess their effectiveness.	26.9%
We do not use our human error data.	10.8%

**Figure 6.** Fatigue Management System and Training by Regulatory Authority Model.

evident in that only 35.9% reported that their organization provided training on fatigue management. However, regulatory adherence was found to have an impact with TC (45.2%) and EASA (40.8%) reporting higher figures than the other regulatory models (Fig. 6).

Human Factors Metrics

Nearly one-third (30.8%) of the organizations conduct formal HF audits but less than one-quarter (22.6%) have an audit planned for 2006-2007. Over half (54.4%) measure the economic and other effects of errors/incidents. At present, less than 10% performed a cost-benefit to justify their HF interventions. However, 51% recognized that their company must improve their return on investment data regarding HF.

For some respondents, realization of the benefits from this investment has begun, with 27.2% reporting cost-

benefit success stories as a result of their HF interventions. When asked for examples of success stories, respondents shared that their companies experienced a reduction in errors, improved on-time performance, improved workplace design, and reduced on-the-job injuries.

DISCUSSION

The high response rate (66%; N=414) from experienced personnel (65% had 20+ years) from more than 50 countries is indicative of the high level of international interest in maintenance HF. The respondent sample likely represents the world's best-case examples due to the voluntary nature of the available addresses. The largest number of respondents was somewhat evenly divided between airlines and repair stations, with representatives from training organizations and general aviation (GA) maintenance facilities also participating. The generalizations here are most reflective of larger maintenance organizations. That is appropriate, since they were the primary target audience of the study. Forty percent of the respondents were from the U.S., which is also consistent with the current distribution of international aviation maintenance activity. (K. Michaels, personal communication, February 11, 2007). In summary, we can attribute reasonably accurate conclusions due to our diverse international participation.

During the design of this study, we expected to find extensive differences among countries because of national regulations regarding HF. The charts presented throughout this report have shown rankings, level of interest, and the nature of HF programs based mostly on regulatory model. There were more similarities than differences in the data.

Maintenance organizations institute HF initiatives because such programs help ensure flight safety and worker safety. Most respondents rated those factors as highly important. Of course, regulatory compliance is very important for companies modeling regulations from TC and EASA, as shown in the data. Nearly 1,200 U.S. repair stations comply with EASA regulations; therefore, they are also motivated by requirements beyond the FAA.

Respondents rated cost issues as the fourth most important reason for having an HF program. It is admirable that safety and compliance are rated highly.

Support From the Regulator

TC was reported as providing the most support as a regulator. The FAA, EASA, and other local national authorities received about the same rating for their support. In response to these findings, the FAA, through the Flight Standards Service organization and, hopefully, other authorities, will identify the best ways to empower the

Aviation Safety Inspector workforce to provide additional HF support to the industry. One example of recent FAA MHF support to the industry is the *Operator's Manual for Human Factors in Aviation Maintenance* (FAA, 2006a). The manual was written to assist companies with developing a quality MHF program. The FAA is also revising the MHF Web site (www.hf.faa.gov) and is developing a new edition of the Web-based Human Factors Guide for Maintenance and Inspection. The FAA Flight Standards Service is also taking proactive measures to enhance and clarify additional guidance material for industry and for FAA personnel. Additionally, Flight Standards extended a previous Aviation Safety Inspector two-day maintenance resource management course to three days with additional coverage of HF topics.

Providing Human Factors Suggestions

Over half of respondents reported that there were means for workers to provide HF suggestions to the company. EASA-modeled companies were well above the average. This is a very positive finding that is likely related to the European requirements for significant HF initial and continuation training for everyone, including managers. The result is that HF issues and language became a shared value among all segments of the workforce. That appears to be happening in Europe, and the rest of the world is evolving in a similar fashion.

Event Reporting – The Good News

We were extremely encouraged to see the level of agreement regarding formal application of event investigations. Most had a formal or informal system. Over two-thirds of respondents said they were using Boeing's MEDA or some modification. This extensive use of the same reporting format could foster data-sharing sometime in the future. Event reporting systems are the fundamental foundation for excellent HF programs and also for safety management systems.

Industry Involvement

Another similarity among the respondents was their company's and their personal involvement in industry and government committee work related to HF in maintenance. Over a third of the respondents participated in such activities. This figure reinforces the earlier statement that our respondents represent the industry's best companies. Of course, this could also be an area of improvement.

With respect to formalized business processes and safety policies, there were similar responses from most respondents. That means that a transition to Safety Management System will not be a difficult concept for many maintenance organizations.

Differences in Responses

Over half of respondents indicated that their company had an existing HF course. Respondents who modeled the FAA had the lowest figure regarding having an existing HF training course. In response to the same question, respondents modeling TC and EASA reported over 75% percent. Because HF courses are not a regulatory requirement in the U.S., it was not surprising to find the largest percentage where no course existed was from companies that modeled the FAA. Obviously, this suggests that regulations are a reliable means of ensuring the presence of an HF training program.

Training the Trainer

As mentioned above, it is reasonable to expect that companies that model their program in accordance with FAA regulations would have less training than companies that were required to have training. The question related to background training of HF trainers clearly indicated that HF trainers of companies which designed their programs in compliance with FAA regulations had less formal training in comparison to the rest of the world. Companies modeling FAA regulations were at the bottom of the ratings with respect not only to HF training but also for train-the-trainer instruction for HF trainers. For respondents that modeled FAA regulations, 23% indicated that their HF trainers had no formal training.

Many HF instructors build their company-specific course from the general materials they obtain by participating, as students, in other courses. A multitude of such courses can be found with a simple Internet search. The importance of such training, for the trainers, cannot be discounted. Of course, trainers can also gain a lot of knowledge by their participation on industry committees, attending conferences, and relying on self-study materials.

Getting the Information to Management

Training and safety personnel who are involved in HF programs are frequently in a position to hear stories about events that often are not significant enough to warrant formal reporting. However, these small events lead to larger ones. Thus, attention to small events will prevent larger ones. About 40% of the respondents said that HF personnel have formal means to communicate human factors issues to senior management. While that is a respectable number, there is significant opportunity to expand such communication. Scheduled meetings, bi-weekly or monthly, dedicated to the discussion of human error and events in the maintenance environment is a very easy way to formalize this reporting.

The Human Factors of Technical Documentation

Proper use of technical documentation remains a high priority for the industry. Failure to follow procedures is the number-one cause of most negative events. Often the failure to use the documentation is associated with an HF-related issue. Many respondents' companies had a formal or informal policy to apply HF considerations to the development or modification of documentation. Effective use of error-reporting systems is an excellent way to raise human factors-related attention to technical documentation and procedures. Event investigations must drill down to the reason(s) that people did not use the documents. HF issues are often a root cause of documentation-related events.

Using Error Data – The Challenges

We have already commented on the excellent efforts to investigate, report, and record event data. A majority of respondents said that event investigations lead to recommendations. However, fewer respondents reported that processes and procedures were changed in the last year as a result of the event database. We found that slightly over a quarter of companies have evaluated the effectiveness of their interventions. These numbers strongly suggest that the error data are not being used to its full potential.

Human Factors Metrics

Thirty-one percent reported that their organization conducted some type of HF audit. Fewer respondents were planning such an audit for 2006-2007. These questions did not define what was meant by HF audit; thus, it is difficult to draw reasonable conclusions about audits. However, the numbers are low; thus, this appears to be a fertile opportunity for improvement.

Over half of the respondents reported that their company measured the cost of events. Few respondents' companies tried to cost-justify HF interventions, while over half of the respondents recognized the importance of demonstrating the return-on-investment in human factors programs. The *FAA Operator's Manual for Human Factors in Aviation Maintenance* offers a method to calculate return on investment. However, to do this properly, companies must track errors, estimate the cost of errors, and the cost of the interventions to calculate savings. As previously noted, few companies are tracking errors and interventions over time, which makes calculating savings over time impossible.

Fatigue Management Systems

One of the strongest findings of this survey is related to fatigue in aviation maintenance. The majority of respondents acknowledged the impact of fatigue on maintenance work. However, only a quarter of them had

a fatigue management system and slightly over a third delivered training related to fatigue management. These numbers strongly suggest that the aviation maintenance industry and the regulators must monitor this situation and implement programs to ensure that worker fatigue management systems provide continuing safety.

IN SUMMARY

This study reinforces the belief that maintenance human factors (MHF) programs are valuable and important, and there are a variety of such programs throughout the world. For organizations that model agencies with regulatory requirements, the HF programs are more widely adopted, and the HF instructors are given more training to prepare them for their responsibilities. Regardless of the variety of international regulations on MHF, the industry reports that flight safety and worker safety are the primary reasons to have such programs.

HF programs reduce cost and foster continuing safety and control of human error in maintenance. This survey found that the best targets of opportunity for improvement are use of event-data reporting, creation of a fatigue management program, and increased use of data as a means of tracking errors over time to justify the cost of HF programs.

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APPENDIX A

International Survey of Human Factors Status in Maintenance Organizations

Welcome to the International Survey of Maintenance Organizations. This survey is designed to assess the present state of human factors in the international aviation maintenance industry. The survey items target key human factors issues such as training, error investigation and company safety policies. We are interested in what human factors elements your organizations are implementing and if those initiatives are designed to meet the requirements of the FAA, EASA or other regulatory bodies. We will distribute a final report describing the results of the survey when completed.

The Civil Aerospace Medical Institute (CAMI) adheres to World Medical Association ethical standards, public law, and federal policies for safeguarding the information submitted by participants in this survey. This information will be protected to the extent available under applicable laws and regulations and no individually identifiable information will be included in the published report. Additionally, identifying information will not be retained once the data collection is done. Participation in the survey is completely voluntary. Please feel free to make any comments that you have regarding the survey in the comment section at the end of the survey. This survey has been approved by the OMB (#2120-0713).

Please skip any item on the survey that you feel does not apply to you or your organization, as well as those that you do not feel qualified to answer.

If you feel that the majority of the questions do not apply to you or your organization, you may exit the survey at anytime by clicking the 'Cancel Survey' button on Page 5. Exiting the survey early will not exclude you from receiving the final report.

1. Do you work for a... (Please select one response.)

- Airline Maintenance Department
- Repair Station (Maintenance, Repair, Overhaul-- Entire A/C)
- Repair Station (Maintenance, Repair, Overhaul-- Components only)
- Manufacturer
- General Aviation/ Business Aircraft Operations
- Military/Government Fixed Base Operator
- Other Military/Government
- Maintenance School/Training Facility
- Other

(Display when response for item 1 is "Repair Station (Components only)" or "Airline Maintenance Department or Repair Station (Entire A/C).")

What type of airline maintenance operation do you work for?

- Major Carrier
- Regional Carrier
- Air Taxi/Charter Operator
- Corporate

2. In which country are you currently employed? (Please type answer below.)

3. Which is the **primary** regulatory authority your maintenance operations are designed to be in compliance with?

- Civil Aviation Safety Authority (CASA)
- European Aviation Safety Agency (EASA)
- Federal Aviation Administration (FAA)
- Transport Canada
- Other National Aviation Authority

(Display when response for item 3 is "Other NAA.")

Please specify your primary maintenance human factors regulatory requirements: *(Text box provided)*

4. How many employees work for your Maintenance and Engineering Department or company?
(Please enter number.)

5. What is your job title?

- Human Factors Manager
- Quality VP/Director
- Quality Manager
- Maintenance VP/Director
- Maintenance Manager
- Human Factors Trainer
- Labor Organization Representative
- Other

(Display when response for item 5 is "Other.")

Please specify your job title: *(Text box provided)*

6. How many years of aviation maintenance experience do you have?

- Less than 1 year
- 1-5 years
- 6-10 years
- 11-15 years
- 16-20 years
- More than 20 years

7. What is your organization's approach to human error investigations?

- A formal process or program
- An informal process or program
- No process or program, however one is being planned for implementation
- No process or program and no immediate plans

(Display when response to Item 7 is "A formal process or program" or "An informal process or program")

Which of the following approaches does your operation use to investigate human error? (Please select all that apply.)

- Maintenance Error Decision Aid (MEDA)
- Human Factors Analysis and Classification System (HFACS)
- Our own modification of MEDA
- Other

If you selected “Other” please specify the approach used to investigate human error in your maintenance operations: (*Text box provided*)

8. How are your human error data being used? (Please select all that apply.)

- We review our error database periodically to identify concerns and plan interventions.
- Within the past year, processes and procedures were changed as a result of the analysis of the error database.
- Within the past year, we bought new tooling or enhanced the workplace because of human factors issues identified in the error database.
- We review our error database to assess the effectiveness of interventions.
- Senior management uses the information as part of a formal quality management process.
- Recommendations are made from individual incidents investigated.
- Recommendations are monitored to see if they are implemented.
- Interventions are evaluated to assess their effectiveness.
- We do not use our human error data.

9. Does your company participate in the FAA’s Aviation Safety Action Program for voluntary error reporting?

- Yes
- No
- Initiating actions to participate

10. Are your human error investigation data in a database?

- Yes
- No
- Do Not Know

11. Does your company track corrective actions as a part of your formal process to manage human error events?

- Yes
- No
- Do Not Know

12. Does your company have a written discipline policy regarding error reporting?

- Yes
- No
- Do Not Know

13. Does your company conduct a formal human factors audit in your maintenance organization?

- Yes
- No
- Do Not Know

14. Does your company have a maintenance human factors audit planned for 2006-2007?

- Yes
- No
- Do Not Know

15. How many formal human error event investigations has your company conducted in the past 12 months? (Please enter number.)

16. Additional Comments on human error management (*Text box provided*)

17. Does your company have maintenance human factors personnel with an academic degree in a human factors-related discipline?

- Yes
- No
- Do Not Know

18. Does your company have maintenance human factors personnel with work experience in human factors?

- Yes
- No
- Do Not Know

19. Does your human factors specialist prepare the curriculum and teach your maintenance human factors course?

- Yes
- No
- Do Not Know

20. Does your company introduce human factors as part of your new employee training for maintenance personnel?

- Yes
- No
- Do Not Know

21. Does your company offer human factors continuation training to maintenance personnel?

- Yes
- No
- Do Not Know

(Display when response for Item 21 is "Yes.")

How many hours of human factors continuation training for each licensed aircraft maintenance engineer/mechanic are offered per 2-year period? (Please enter a numeric response.) *(Text box provided)*

22. Does your company offer human factors continuation training to all staff?

- Yes
- No
- Do Not Know

23. About what percentage of your managers has received at least 4 hours of human factors training? (Please enter a percentage between 0 and 100.)

24. About what percentage of your **licensed** aircraft maintenance engineers/licensed mechanics has received at least 4 hours of human factors training? (Please enter a percentage between 0 and 100.)

25. About what percentage of your **unlicensed** aircraft maintenance engineers/mechanics has received at least 4 hours of human factors training? (Please enter a percentage between 0 and 100.)

26. About what percentage of your maintenance support staff has received at least 4 hours of human factors training? (Please enter a percentage between 0 and 100.)

(For questions 27 to 31: Our/We refers to your maintenance organization.)

27. Our organization's current position regarding human factors training is:

- We have an existing course that meets the requirements.
- We are in the process of developing a course to meet the requirements.
- We send our employees to existing courses or hire a consultant to do this training.
- We do not have any plans for development of such a course.

(Display when response for Item 27 is "We have an existing course that meets the requirements" or "We are in the process of developing a course to meet the requirements.")

The human factors course covers the following areas: (Please check all that apply.)

- Introduction to human factors
- Effect of shift work and fatigue on performance
- Communications (e.g., Inter-team, Crew Resource Management)
- Factors that contribute to human error
- Event investigation
- Shift turnover
- Other

If you selected "Other" please specify the areas your human factors course covers: *(Text box provided)*

The course(s) is designed for: (Please check all that apply.)

- Licensed Aircraft Maintenance Engineers/Mechanics
- Non-licensed Aircraft Maintenance Engineers/Mechanics
- Trainers
- Supervisors/Managers
- Quality Auditors
- Planners
- Degreed Engineers
- Other

If you selected "Other" please specify who your human factors course was designed for: (*Text box provided*)

28. We recognize the return on investment value of initial human factors training.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

29. We recognize the return on investment value of recurrent human factors training.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

30. We recognize the value of proactive human factors programs.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

31. We measure the economic and other effects of errors/incidents.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

(Our/We refers to your maintenance organization.)

32. What training do your human factors trainers have: (Select all that apply)

- Academic degree in human factors or related field
- Have a University/College diploma
- Attended a short (2-5 days) human factors trainers course
- Attended a short (2-5 days) instructor skills course
- Have maintenance/engineering work experience
- Are licensed mechanic/engineers
- Have no formal training

33. Our human factors trainer(s): (Select all that apply)

- Develop the training content and materials
- Use materials the company purchased
- Use freely available materials
- Need more training materials

34. Human factors is introduced as part of our new employee training for maintenance personnel:

- One day course
- Two day course
- Computer-based course
- Other

35. Additional Comments on human factors training. (*Text box provided*)

36. We have a fatigue management system.

- Yes
- No
- Do Not Know

(Our/We refers to your maintenance organization.)

37. We provide training on fatigue management.

- Yes
- No
- Do Not Know

38. We recognize that fatigue is a safety issue.

- Yes
- No
- Do Not Know

39. Our manager/director of maintenance actively supports maintenance human factors in words and in actions.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

40. We have a formal means for supervisors and workers to provide suggestions on human factors issues.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

41. We have a formal method for our human factors specialist(s) to provide regular briefings to senior maintenance management.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

42. We receive support from our regulator (e.g., Federal Aviation Administration, European Aviation Safety Agency, Joint Aviation Authorities, or National Aviation Authority) in the design and implementation of our human factors program.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

43. We work very closely with our regulator (e.g., FAA, EASA, JAA, or NAA) to monitor our human factors program.

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

44. We are active participants in industry or government human factors working group(s).

- Strongly Disagree
- Disagree
- Neither Disagree nor Agree
- Agree
- Strongly Agree

Please rate the relative importance of each factor in the decision of your organization to implement a human factors program.

45. Regulatory Compliance

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

46. Flight Safety

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

47. Worker Safety

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

48. Cost

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

49. Does your company have a safety policy?

- Formal Policy
- Informal Policy
- No Policy

50. Does your company have a policy to apply human factors principles in writing or amending procedures?

- Formal Policy
- Informal Policy
- No Policy

51. Does your company have a shift handover policy?

- Formal Policy
- Informal Policy
- No Policy

52. Does your company have a policy for considering human performance limitations in production planning?

- Formal Policy
- Informal Policy
- No Policy

Please rate the importance of these factors on your company's safety management system.

53. Formal human factors program

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

54. Human factors training

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

55. Fatigue management

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

56. Error reporting system

- Not At All
- Limited Importance
- Moderate Importance
- Considerable Importance
- Great Importance

(Our/We refers to your maintenance organization.)

57. We have a formal quality assurance program like ISO9000 or a continuous improvement program.

- Yes
- No
- Do Not Know

58. Our quality assurance program explicitly addresses human factors.

- Yes
- No
- Do Not Know

59. We ensure that our service providers and suppliers have a quality assurance program.

- Yes
- No
- Do Not Know

60. We have an explicit line item in the budget for human factors interventions.

- Yes
- No
- Do Not Know

61. Additional comments on proactive actions taken to support a human factors program at your company. (*Text box provided*)

62. We perform a cost-benefit or return on investment calculation to justify our human factors interventions.

- Yes
- No
- Do Not Know

63. Our management demands return on investment calculations in our proposed program plans.

- Yes
- No
- Do Not Know

64. We have success stories and positive examples of the cost-benefit of our human factors interventions.

- Yes
- No
- Do Not Know

(Display when response for item 64 is "Yes".)

Please share your success stories of the cost-benefit associated with your human factors interventions.

(*Text box provided*)

(*Our/We refers to your maintenance organization.*)

65. We must improve our return on investment data regarding human factors programs.

- Yes
- No
- Do Not Know

66. Our return on investment efforts have demonstrated the value of safety-related human factors interventions.

- Yes
- No
- Do Not Know

67. Additional comments on your company's maintenance program. (*Text box provided*)

68. Please enter your comments and suggestions about this survey. (*Text box provided*)

APPENDIX B
List of Countries Responding to Survey

Argentina	Kuwait
Australia	Luxembourg
Austria	Malaysia
Bahrain	Malta
Belgium	Mexico
Bolivia	Netherlands
Brazil	New Zealand
Canada	Norway
Chile	Panama
China	Peru
Colombia	Philippines
Cyprus	Poland
Denmark	Portugal
Ecuador	Romania
El Salvador	Singapore
Finland	Slovenia
France	South Africa
Germany	Spain
Greece	Sweden
Greenland	Switzerland
Guatemala	Taiwan
Hong Kong	Thailand
Hungary	Turkey
Ireland	United Arab Emirates
Italy	United Kingdom
Japan	United States of America
Korea	Venezuela

